

OVERVIEW OF CHEMCAM ACTIVITIES AND DISCOVERIES DURING 4 YEARS AT GALE CRATER, MARS.

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Introduction: The first extraterrestrially employed LIBS instrument is ChemCam [1,2] on NASA's Mars rover Curiosity [3], which has been successfully analyzing materials on the martian surface since the rover's landing in August 2012. Since then, the rover drove more than 13 km from the Bradbury landing site southwest to the Bagnold Dunes and is now approaching the Hematite Ridge at the foothills of Mount Sharp.

ChemCam is composed of two instruments: a LIBS instrument for assessing the chemistry of targets in distances of up to 7 m and a Remote Micro-Imager (RMI) [4] that provides high resolution context images. ChemCam serves as a reconnaissance tool to identify potentially interesting targets for further analysis with more laborious and time-consuming methods as well as a primary scientific tool for independent qualitative and quantitative determination of sample composition at the submillimeter scale.

Major Findings of ChemCam along the traverse: Within the first 1300 days of the mission over 330.000 ChemCam LIBS spectra of soils and rocks were recorded in Gale crater, analyzing more than 1200 targets and taking more than 5400 RMI images [5,6]. Additionally, many ChemCam passive spectra (i.e. without lasing) have been recorded and analyzed [7, 8]. The numerous analyses revealed the compositional diversity of the igneous rocks, the sedimentary rocks, and the diagenetic features.

Bradbury Rise: The Bradbury landing site, a plain located at a distal portion of the alluvial fan from Peace Valis, exposed several float rocks [9,10] presenting igneous compositions ranging from mafic up to a trachytic endmember [11]. These observations provided an important clue concerning the diversity of early Mars magmatism that was not previously recognized. More igneous float rocks have been observed all along the traverse, being more felsic closer to the landing site, and more mafic near the cratered unit, after the Kimberley formation [12].

Sheepbed and Shaler: The Sheepbed area is essentially composed of mudstones that show a very homogeneous composition, close to the average Martian crust, providing evidence of aqueous episodes with little alteration in this area. ChemCam showed that the bedrock host experienced other diagenetic events with Mg- and Fe-rich clays in erosion-resistant raised ridges on one hand, and calcium sulfate veins on the other hand. The nearby Shaler fluvial sandstone outcrop [13], the first outcrop of potential deltaic foreset beds, shows K enrichment.

Conglomerates have been analyzed in detail all along the traverse as they represent a link between the source rocks and the finer-grained sediments such as the sandstones and mudstones. They have shown an average composition that is enriched in alkalis, Al, and Si compared to the average Martian crust, with a clear enrichment in K₂O in the vicinity of the Kimberley formation [14]. Enrichment in K₂O at Kimberley in conglomerates and in sandstone outcrops reveals the presence of an alkali-rich source rock [15, 16].

Pahrump: Further along the traverse, the Pahrump outcrop corresponds to the first observed material at Mt Sharp's base and is part of the Murray Formation, mainly constituted of mudstones. Its facies suggest a stronger alteration, with presence of F-bearing materials such as apatite, fluorite and phyllosilicates [16]. Both Murray and Stimson formations (overlying unit) are highly enriched in SiO₂ (>80 wt.%). This enrichment in Si could be due to deposition of Si [17,18], but acidic alteration or hydrothermalism [16,19] are also possible explanations.

ChemCam analyzed > 200 soil locations. The analyses indicate that fine-grained soils have a mafic composition that nevertheless contains contributions from local bedrocks. Analysis of coarser grains gave the possibility to study the link between local rocks and soils. ChemCam also adds new information on the ubiquitous hydration of these soils [20,21]. Soils investigated in the last half year on Mars and the Bagnold dunes materials contain less altered phases and are overall similar in composition to previously encountered soils with low volatiles [23]. Here, the coarser grains seem to be more mafic.

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